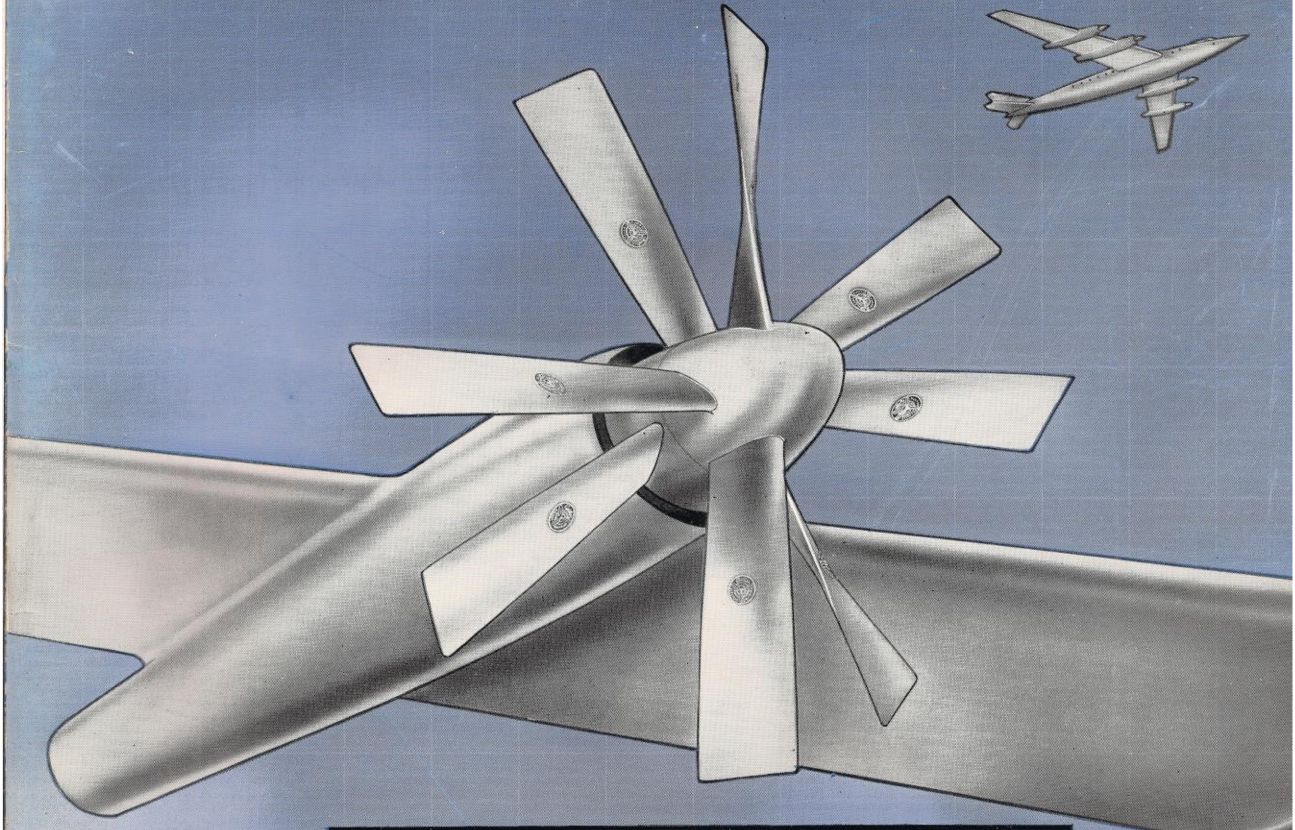

CURTISS *Turbolectric* PROPELLERS

FOR

TURBO-PROP ENGINES

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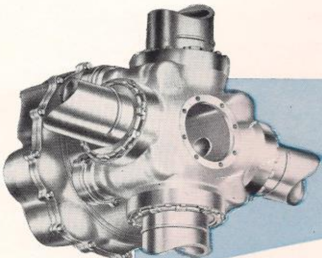
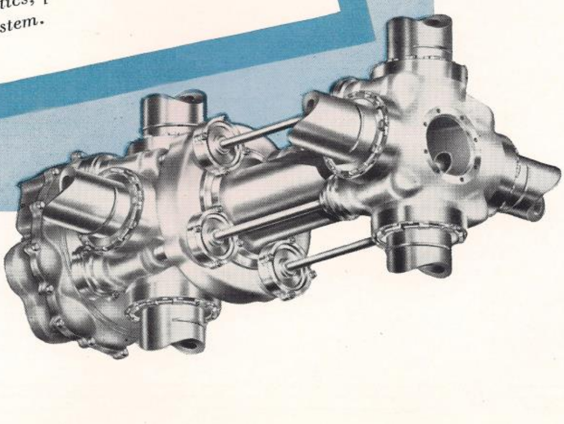


Introducing

The Curtiss "Turbolectric" Propeller

The Propeller Division of the Curtiss-Wright Corporation proudly introduces a new series of propellers, especially designed to meet the exacting requirements of the turbo-prop engines and to convert efficiently the output of these engines into propulsive thrust.

This brochure presents a description of the new Curtiss "Turbolectric" Propeller, including aerodynamic characteristics, pitch changing mechanism, and control system.



The Curtiss "Turbolectric" Propeller

The Curtiss "Turbolectric" Propeller is designed especially for use with aircraft turbo-prop engines. Compared to the piston type engine, the aircraft turbo-prop engine is essentially a constant-speed power plant, developing much higher powers for a given size and weight, but having more critical over-speed and over-temperature limits. Propellers for these new engines must, therefore, absorb greater power and have more exacting control response characteristics than is required for use with conventional reciprocating engines.

High Efficiency

The most recent advancements in propeller design have been incorporated in this new series of propellers to provide, at the higher powers and speeds, efficiencies even greater than those which have been found possible with the former applications on reciprocating engines. These high efficiencies have been made possible by careful refinement of the blade pitch distribution, section thicknesses, and planform.

Advantages

The "Turbolectric" is the newest addition to the long list of Curtiss-Wright propellers which have proven so successful during many years of dependable operation on aircraft equipped with piston-type power plants. Note these outstanding advantages:

1. **POSITIVE ELECTRO-MECHANICAL PITCH CHANGE.**
The pitch change mechanism has been designed to match the exacting response characteristics of turbo-prop engines at all operating conditions, regardless of temperature or altitude. The design incorporates basic mechanical principles of operation, already proven in Curtiss-Wright propellers operating on the giant B-36 superbomber.

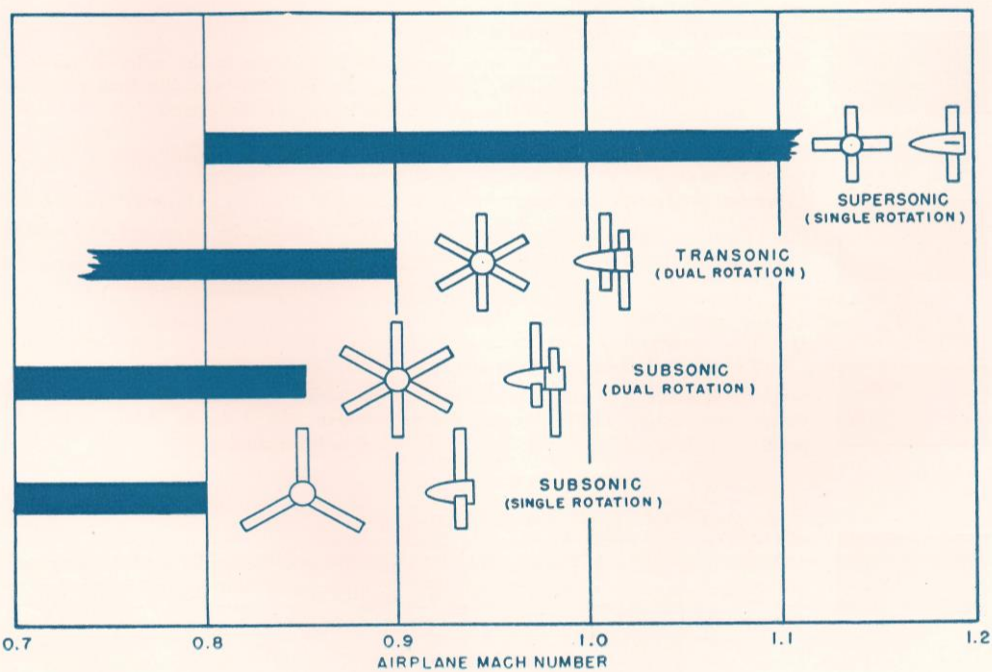
2. **VERSATILE, COORDINATED, ELECTRO-MECHANICAL CONTROLS.**
The simplicity and reliability of the electro-mechanical control system contrast sharply with more complicated hydraulic or electronic methods and greatly simplify the initial concepts believed necessary for turbo-prop control. The system utilizes simple mechanical components working in combination with an electrical source of speed reference and provides these advantages:
    a. Reliability under all flight operating conditions and altitudes.
    b. Adaptability to either single or dual-control lever arrangements.
    c. Automatic synchronization for multi-engine aircraft.
    d. Ease of installation and maintenance.

3. **RUGGED CONSTRUCTION WITH MINIMUM WEIGHT.**
The "Turbolectric" propellers will use the familiar Curtiss monocoque hollow steel blade and single-unit hub construction, which is particularly adaptable to the structural requirements of high-speed turbo-prop applications and has a background of many million propeller hours of operation on both military and commercial aircraft.

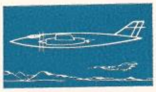
4. **SAFETY AND DEPENDABILITY**
The "Turbolectric" propeller provides the safety and dependability of reverse thrust, elecrtical or heated-air de-icing, and rapid feathering, with provisions for automatic feathering, if desired.

Application of Propellers for Turbo-Prop Engines

The general aerodynamic requirements for propellers on turbo-prop engines are similar to those for propellers on reciprocating engines. However due to the considerably higher powers available with these turbo-prop engines and resulting high aircraft performance, several types of propellers will be required, which may be classified as single-rotation subsonic, dual-rotation subsonic and transonic, and single-rotation supersonic. These propellers will be available for application on aircraft operating in several speed ranges as shown in the diagram below.

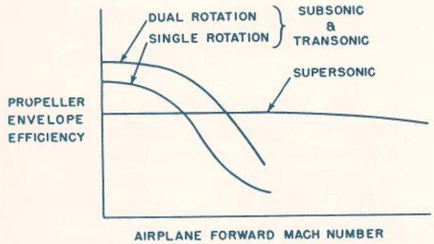


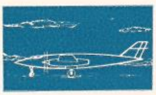
Aerodynamic Characteristics



Flight Efficiencies

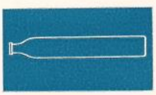
The blades developed for the Curtiss "Turbolectric" Propeller incorporate the most advanced aerodynamic refinements. Flight efficiencies of the subsonic and transonic propellers will be at substantially high levels, with values of 80—90% at cruising speeds and 80% at high speeds up to 0.80 Mach number, as proven by flight and wind-tunnel tests. Supersonic propellers will maintain equivalent high speed efficiency into the sonic region, as indicated by the efficiency envelope curve shown in figure at the right.





Take-off Performance

Take-off performance will also be at comparatively high values in the order of 1.5 to 3 pounds static thrust per horsepower, depending on the propeller type, installation requirements, and emphasis placed on obtaining optimum high-speed efficiencies.



Blade Planform

Blade Planform will be essentially rectangular. High blade activity factor and total solidity will efficiently absorb the large powers developed by turbo-prop engines.

Section Thickness

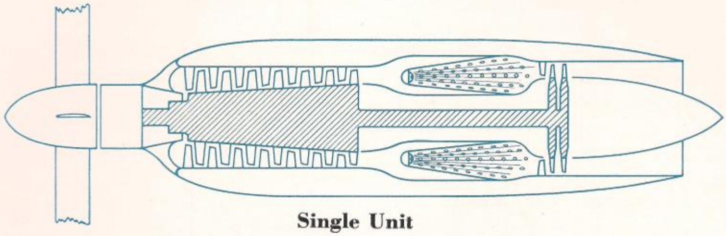
Section thickness will be as thin as possible, consistent with structural integrity, to obtain optimum performance. Thickness ratios will be less than .050 at the ¾ radius station, depending on the aerodynamic vibration excitation of each installation.

Airfoil Sections

Airfoil sections will be the low drag NACA 16- or 6X-series. Design lift coefficients or camber will be selected to provide the optimum performance defined by the installation requirements.

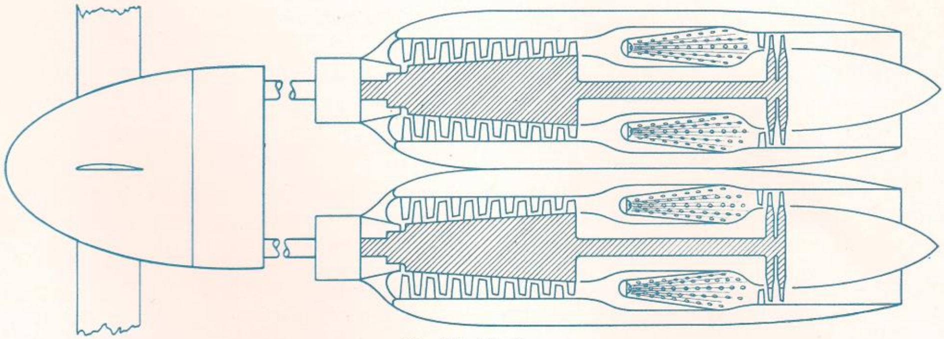
Turbo-Prop Engines

The Curtiss "Turbolectric" Propeller can be installed on any type of turbo-prop engine, three configurations of which are shown below.



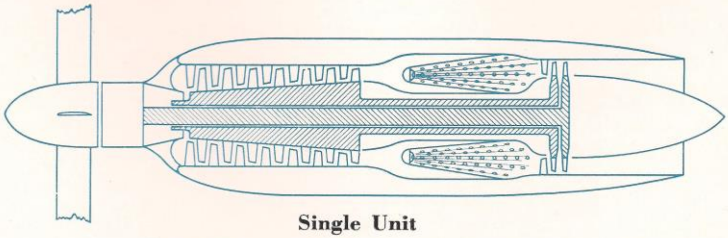
Single Unit

Compressor Coupled to Output Shaft



Double Unit

Two Single Units Driving Propeller Through Common Gear Box



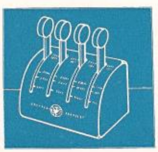
Single Unit

Propeller Driven by Separate Turbine Wheel

Propeller Requirements for Turbo-Prop Engines

In the design of the Curtiss "Turbolectric" Propeller, the control system, structural characteristics, and accessory components have been carefully matched to the special requirements of the turbo-prop engine, thus ensuring an optimum overall power plant installation.

Control System



The turbo-prop engine is essentially a constant-speed power plant, developing maximum performance at maximum permissible rpm and temperature. These must be maintained within very close limits by coordinated adjustment of blade angle and fuel flow. The propeller control, therefore, must be incorporated as an integral part of the turbo-prop engine control system and must insure satisfactory operation throughout all of the airplane operating conditions:

1. **Starting**—Minimum torque blade angle is required to minimize starting loads.

2. **Taxiing and Ground Maneuvering**—Predetermined scheduling of blade angle and fuel flow is required to provide control of engine rpm and power in accordance with the amount of forward or reverse thrust desired.

3. **Take-off and Flight**—Automatic governing of rpm and control of fuel flow is required to provide smooth and rapid power response throughout all flight conditions.

4. **Feathering**— As in all types of propeller-driven aircraft, rapid feathering, overriding all other controls, must be provided. Automatic feathering to quickly reduce windmilling drag due to power failure during take-off can be provided as optional control equipment, if desired.

5. **Landing Approach**—Governing at or near full rpm is required at substantially zero thrust with provision for rapid re-application of power in the event the landing cannot be completed.

6. **Landing Braking**—Aerodynamic braking, which has proven so desirable on reciprocating engine aircraft, is also incorporated as a standard feature of the Curtiss "Turbolectric" Propeller.

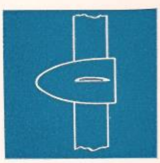
The new "Turbolectric" blade angle governor control, described later, has been developed by the Curtiss-Wright Propeller Division to fulfill the above requirements and is adaptable to match the characteristics of virtually any turbo-prop power and speed control system. This system is based on the control of rpm by means of blade angle adjustment.

An alternate, complete, coordinated turbo-prop control system is also offered for use with the "Turbolectric" Propeller. This system is based on control of temperature by blade angle adjustment and control of rpm by fuel flow adjustment and offers advantages for certain applications.

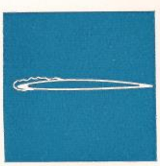
Structural Characteristics

Vibration of propellers, resulting from engine excitation, will be substantially reduced due to the absence of torque impulses and reciprocating forces in turbo-prop engines. On the other hand, propeller vibration due to aerodynamically excited forces, which are independent of the type of power plant, will still be a factor, but can be kept to minimum values by proper thrust line orientation. Airplane manufacturers are, therefore, urged to review their preliminary aircraft designs with the Curtiss-Wright Propeller Division as early as possible to determine the best configuration. This will assure selection of a propeller having an optimum combination of propeller efficiency and weight through the use of blades having the thinnest possible sections.

Accessory Components

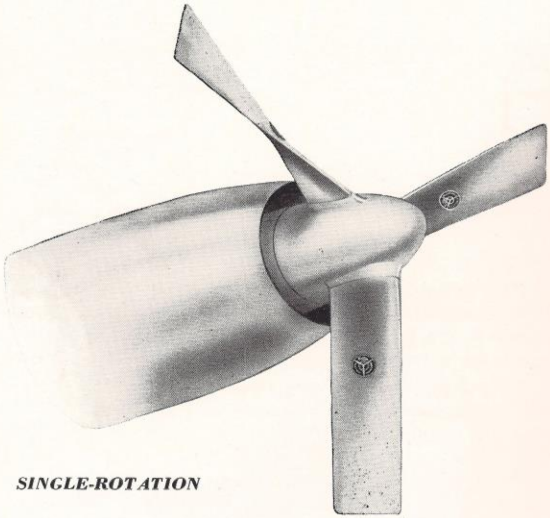


Spinners are provided on all Curtiss "Turbolectric" Propellers to assure maximum pressure recovery for engine intake air and to reduce drag around the propeller pitch change mechanism and blade shanks. These spinners are available in two basic configurations, NACA type D or type E, which are further described on page 17.



De-icing of propeller blades and spinners will be an important consideration in order to avoid the increased drag resulting from ice accretion. The several types of de-icing offered for use with the Curtiss "Turbolectric" Propeller are described on page 17.

"Turbolectric" Propellers



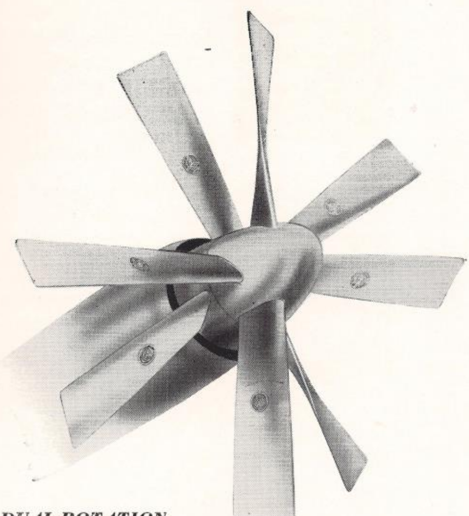
SINGLE-ROTATION

	SINGLE-ROTATION MODELS			
	THREE BLADES		FOUR BLADES	
Model	C634S	C735S	C644S	C746S
Shaft Size	60	70	60	70
Diameter Range (ft.)	13-16	15-19	13-16	17-21
Activity Factor Range	120-150	120-150	120-150	100-150
Weight Range (lbs.) approx.*	650-750	750-900	750-850	1450-1500
Power Range (SHP) (S.L. Static)	2500-5000	5000-7500	5000-7500	7500-10,000

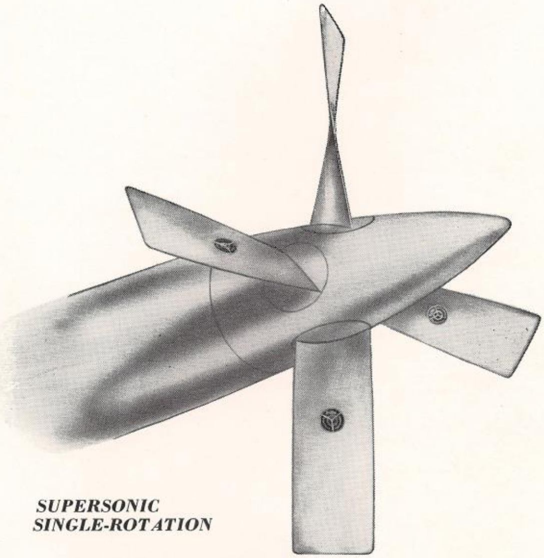
* Exact weight dependent upon specific installation.

	DUAL-ROTATION MODELS			
	SIX BLADES		EIGHT BLADES	
Model	C(68)64S-A	C(658)64S-A	C(658)84S-A	C(89)86S-B
Shaft Size	60L-80	65-80	65-80	80-90
Diameter Range (ft.)	14-16	14-16	14-16	16-18
Activity Factor Range	120-150	120-150	120-150	120-150
Weight Range (lbs.) approx.*	1250-1450	1250-1450	1700-1800	2400-2650
Power Range (SHP) (S.L. Static)	5000-7500	7500-10,000	7500-10,000	10,000-20,000

* Exact weight dependent upon specific installation.



DUAL-ROTATION



SUPERSONIC SINGLE-ROTATION

SUPERSONIC PROPELLERS

Curtiss "Turbosonic" Propellers utilizing supersonic blades in Turbolectric type hubs are under development to meet the requirements of the very high-speed, propeller-driven aircraft now under active consideration. Designed in accordance with the most advanced aerodynamic and structural data, these propellers are expected to offer a definite challenge to turbo-jet power plants, particularly for long-range multi-engine aircraft.

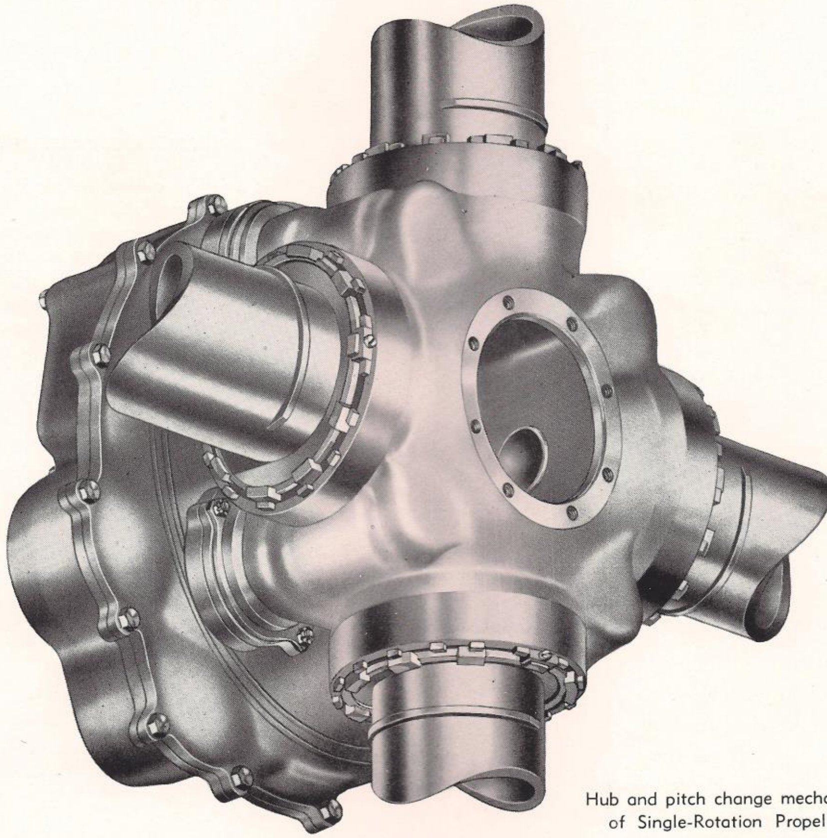
Propeller Configurations

The "Turbolectric" propeller is available in several basic configurations which make possible its application to a wide range of airplane sizes and engine powers. The primary differences between these models are in the number and type of blades required to give the desired airplane performance.

Illustrated on these pages are the single-rotation subsonic propeller, the dual-rotation subsonic or transonic propeller, and the single-rotation supersonic propeller. Each of these types can be supplied to fit any of the applicable turbo-prop engine shaft sizes and can be equipped with blades having activity factors and other aerodynamic characteristics matched to the requirements of the individual airplane.

Pitch Change Mechanism

SINGLE-ROTATION PROPELLERS



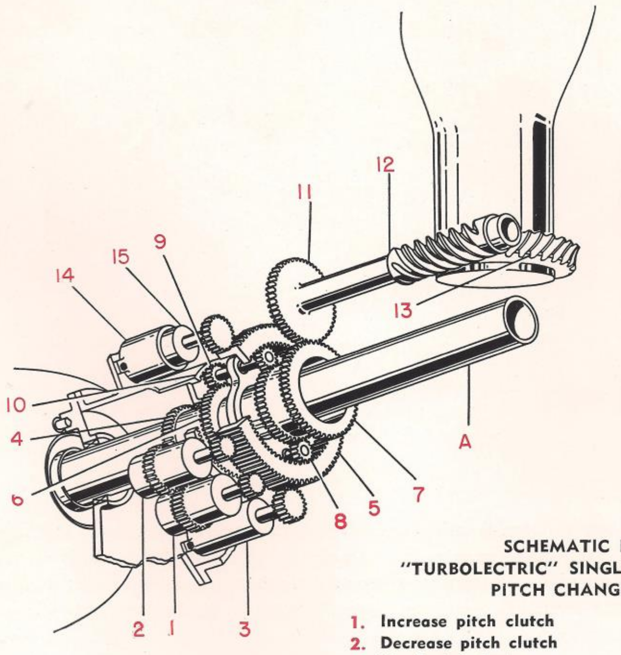
Hub and pitch change mechanism
of Single-Rotation Propeller

Pitch change for the Curtiss "Turbolectric" Propeller is accomplished by a mechanism of unique design which obtains power directly from the rotation of the propeller shaft. Electrically actuated mechanical clutches transmit this power to a differential inter-gearing system located between the stationary housing on the engine nose and the rotating propeller blades.

The operation of the entire system is completely free of any fluid pressure devices and is thus unaffected by ambient temperature or pressure extremes. Since pitch change is actuated positively through gear mechanisms, the control characteristics will not be affected by wear experienced during normal service life.

Referring to the schematic diagram, two electrically energized clutches are used during normal flight operation, one for increase (1) and one for decrease (2) pitch actuation. When a control signal actuates one of these clutches, it also disengages the fixed pitch brake (3). The gearing from the propeller shaft (4) is then coupled through the actuated clutch and the propeller movable ring gear (5) to the inter-gearing assembly. The inter-gearing assembly enables energy to be transmitted from the stationary pitch changing mechanism to the rotating hub. During fixed pitch, the brake (3) is engaged and both propeller shaft sun gear (6) and pitch change sun gear (7) rotate with the propeller shaft or hub, thus rotating the sets of planet gears (8 and 9) which are meshed with the fixed ring gear (10) and the movable ring gear (5), which is then stationary. When power is transmitted by clutch actuation to the movable ring gear (5), it rotates in relation to the fixed ring gear (10). This change of relationship, acting through planet gears (8 and 9), causes the movable pitch change sun gear (7) to rotate in relation to the hub. The pitch change sun gear (7) is coupled to the blade gear (13) through the pinion gear (11) and worm gear (12). Upon completion of the control signal the clutch disengages, and the brake (3) engages to maintain the adjusted blade angle.

To provide the necessary power for effective pitch change operation at low rotational propeller speeds, an electric motor (14) is used for completion of the feathering cycle, initiation of unfeathering, and for adjusting pitch to the starting angle as well as to that for any other static operation. When power is supplied to the feather motor, which is normally disengaged from the gearing by the electric motor clutch (15), the clutch couples the motor to the movable ring gear (5). The electric brake (3) is released when power is supplied to either the clutch or the electric feather motor.



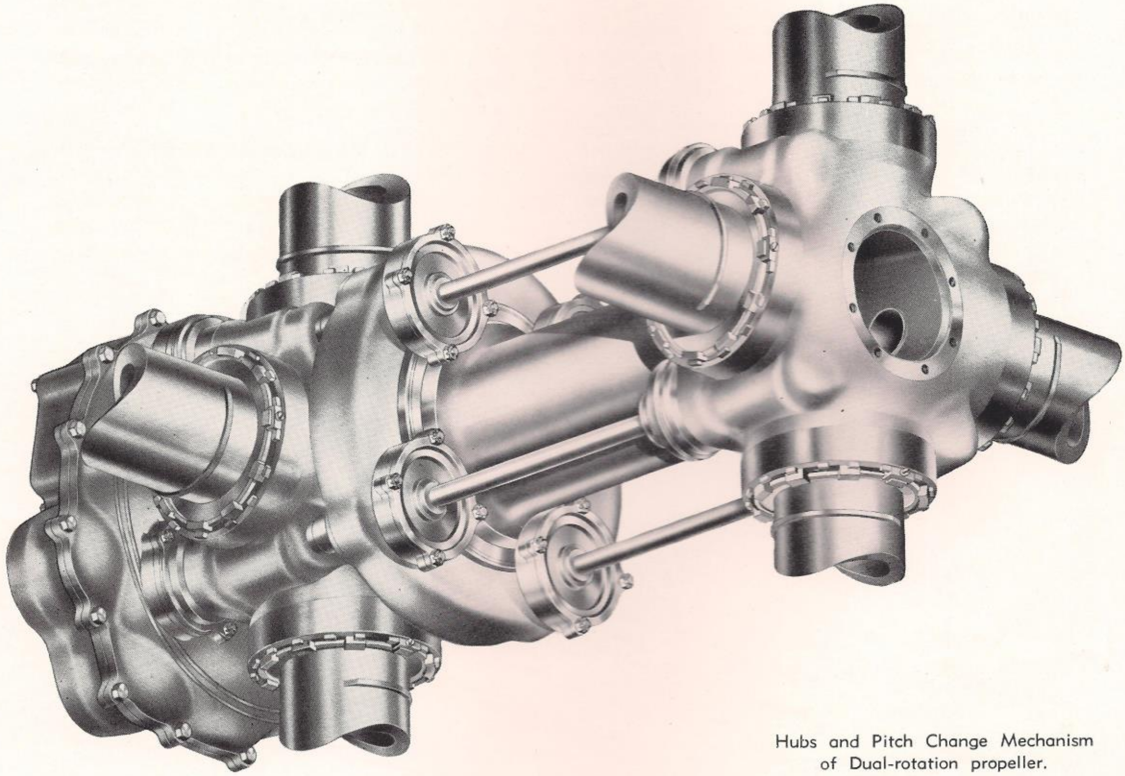
SCHEMATIC DIAGRAM OF "TURBOLECTRIC" SINGLE-ROTATION PROPELLER PITCH CHANGE MECHANISM

1. Increase pitch clutch
2. Decrease pitch clutch
3. Fixed pitch brake
4. Propeller shaft gear
5. Movable ring gear
6. Propeller shaft sun gear
7. Pitch change sun gear
8. Pitch change planet gear
9. Reaction planet gear
10. Fixed ring gear
11. Pitch change pinion gear
12. Blade worm gear
13. Blade gear
14. Electric motor (feathering)
15. Electric motor clutch

A. Propeller shaft

Pitch Change Mechanism

DUAL-ROTATION PROPELLERS

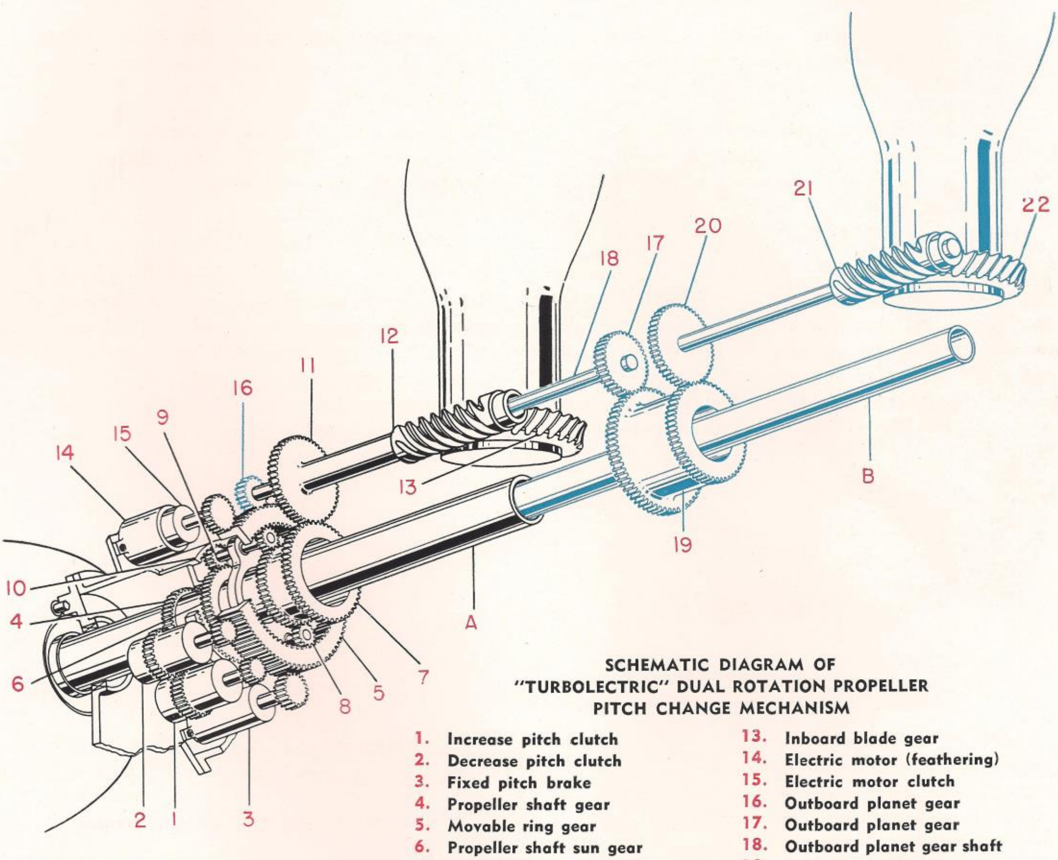


Hubs and Pitch Change Mechanism of Dual-rotation propeller.

The pitch change mechanism for dual-rotation propellers is essentially the same as that used on a single-rotation unit, except for the added gearing required to operate the outboard blades. This outboard gearing is similar to that used to transmit the pitch change power from the stationary housing to the rotating inboard hub, except that the gearing is a partial differential and must operate through the inboard hub which is turning in the opposite direction.

Referring to the sketch below, the outboard planet gears (16-17) are mounted on shaft (18), operating through the pinion and worm gear assemblies (11-12), in the inboard hub. Rotation of the movable ring gear (5) is transmitted through these planet gears (16-17) to the outboard pitch change sun gear (19) which is coupled to the outboard blade gear (22) through pinion gear (20) and worm gear (21). The sizes of planet gears (16-17) have been selected to hold the outboard pitch change sun gear (19) stationary with respect to the outboard hub upon completion of the control signal.

Blade angles and rates of pitch change of the inboard and outboard propellers can be selected to equalize the thrust loading between the propellers as required by the particular installation.



SCHEMATIC DIAGRAM OF "TURBOLECTRIC" DUAL ROTATION PROPELLER PITCH CHANGE MECHANISM

1. Increase pitch clutch
2. Decrease pitch clutch
3. Fixed pitch brake
4. Propeller shaft gear
5. Movable ring gear
6. Propeller shaft sun gear
7. Inboard pitch change sun gear
8. Inboard pitch change planet gear
9. Inboard reaction planet gear
10. Inboard fixed ring gear
11. Inboard pitch change pinion gear
12. Inboard blade worm gear
13. Inboard blade gear
14. Electric motor (feathering)
15. Electric motor clutch
16. Outboard planet gear
17. Outboard planet gear
18. Outboard planet gear shaft
19. Outboard pitch change sun gear
20. Outboard pitch change pinion gear
21. Outboard blade worm gear
22. Outboard blade gear

A. Inboard propeller shaft
B. Outboard propeller shaft

Blade Angle Governor Control System

The governor control system, supplied as part of the "Turbolectric" Propeller, consists of a governor and a coordinator, which are designed to operate in conjunction with the specific power control system of the turbo-prop engine. Schematic diagrams of this system are shown on pages 15 and 16. A typical control system is normally divided into two operating regimes:

(A) **The governing regime** is utilized to provide constant-speed operation during take-off and all flight conditions. Coordinaton of turbine power and propeller blade angle is automatically controlled by the propeller and power coordinators.

(B) **The Beta regime** (blade angle follow-up) is utilized for all ground handling operations, including reverse thrust. Turbine power and propeller blade angle settings "follow up" the position of the power control lever in accordance with a predetermined or scheduled relationship.

GOVERNING REGIME

Operation of the control lever, within the governing regime, changes the settings of both the propeller governor and the turbine control, as scheduled by the propeller and power control coordinators. The governor, shown in Figure 1, is mounted on the aftside of the propeller mechanism and is connected to the pilot's control lever through the propeller coordinator, as shown in Figure 2. This governor, utilizing small differential gears, mechanically compares the rpm of the engine to that of a reference speed source and produces a pitch change signal to correct any existing error. Acceleration sensitivity is provided to obtain highest performance and stability. This "blade-angle-desired" signal from the governor is transmitted to the propeller pitch change

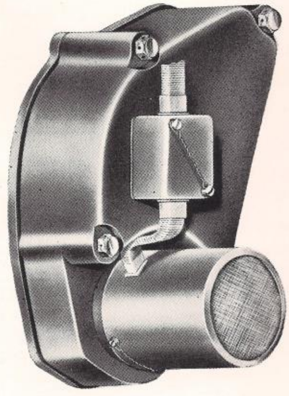


Figure 1 — Blade Angle Governor for "Turbolectric" Propeller

mechanism where it is compared mechanically to the existing blade angle. The output of this comparison controls the operation of the pitch change mechanism. The reference speed source is a synchronous electric motor controlled by a variable frequency power supply in the propeller coordinator. When used on multi-engine aircraft, the power supply can be made to furnish a common reference speed for all engines to obtain synchronized constant-speed operation. The electrical speed reference is supplemented by a stand-by, fly-weight governor which detects any malfunction of the synchronous motor system and automatically assumes control as the reference speed source in the event of such malfunction. A separate switch is provided for manually setting the fly-weight governor in the event an rpm change is desired during stand-by governor operation.

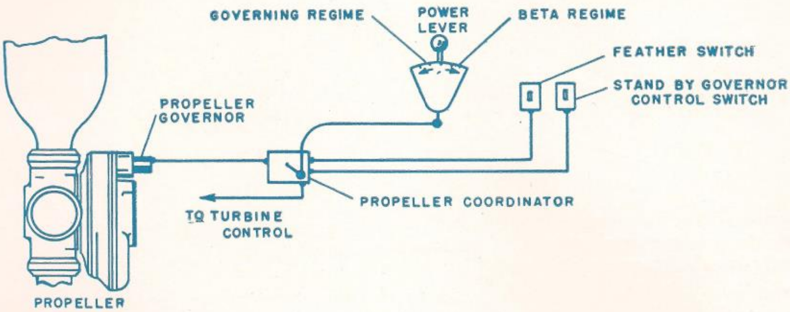


Figure 2—Schematic Diagram of the "Blade Angle" Governor Control System for the "Turbolectric" Propeller.

BETA REGIME

Motion of the power lever in the Beta regime (blade angle follow-up) operates a potentiometer in the propeller coordinator. The output of this potentiometer is compared to the output of a potentiometer on the blade pitch indicator in the propeller and the voltage difference is utilized to signal the required blade angle change.

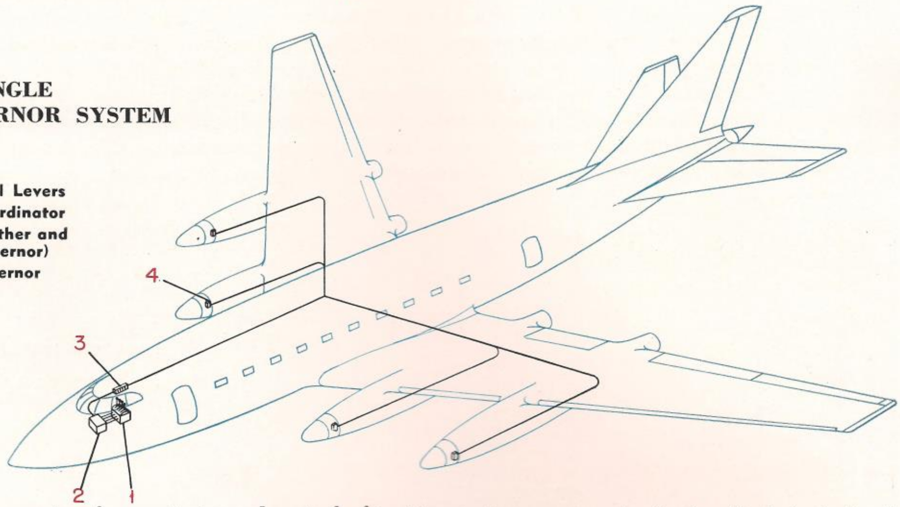
FEATHERING

Feathering is controlled by an individual switch, mounted near the pilot's control lever. Operation of this switch overrides all other controls and energizes the increase pitch clutch directly.

"Turbolectric" Control Systems

BLADE ANGLE PROPELLER GOVERNOR SYSTEM

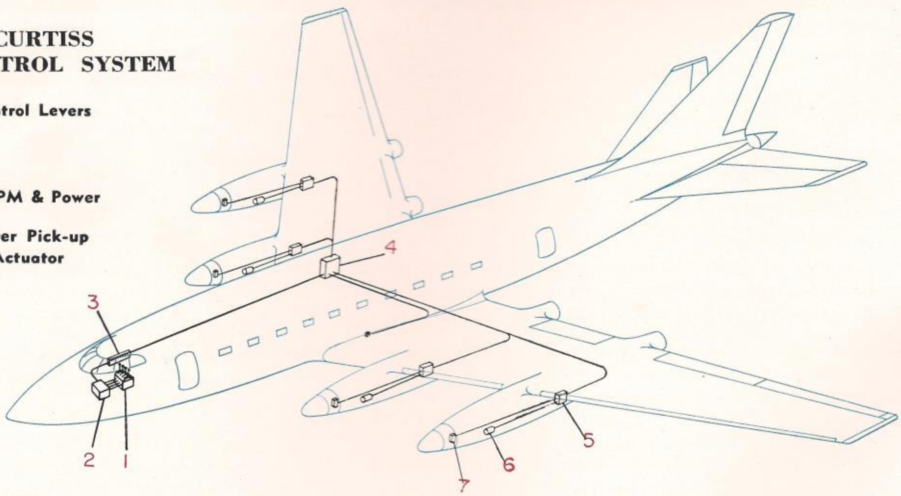
1. **Power Control Levers**
2. **Propeller Coordinator**
3. **Switches (Feather and Stand-by Governor)**
4. **Propeller Governor**



The governor system for constant speed control of turbine engine rpm, previously described, is designed to operate with the power control systems of modern turbo-prop engines. The system consists of a minimum number of easily installed components, located in the airplane as indicated by the above schematic diagram.

COMPLETE CURTISS TURBO-PROP CONTROL SYSTEM

1. **Power Control Levers**
2. **Receiver**
3. **Switches**
4. **Computor**
5. **Turbine RPM & Power Control**
6. **Torquemeter Pick-up**
7. **Propeller Actuator**

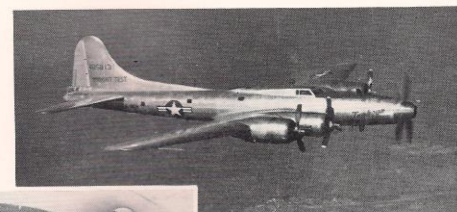


A complete system for coordinated control of both constant speed engine rpm by fuel flow regulation and turbine power by blade angle control is under development for application to turbine engines. For certain applications, this basically different system is believed to offer many advantages. The system, shown schematically above, consists of all components necessary for both propeller and engine controls.

Development of Turbine Propellers

The Propeller Division of the Curtiss-Wright Corporation has been actively engaged in the development of propellers for turbo-prop engine application for many years. Typical examples of this work are shown below.

1



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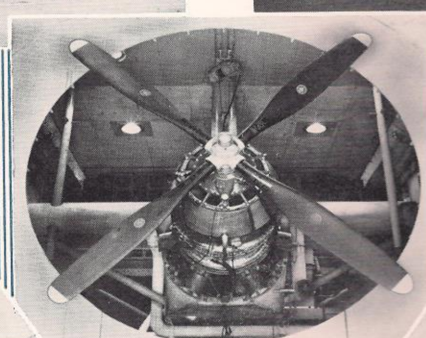

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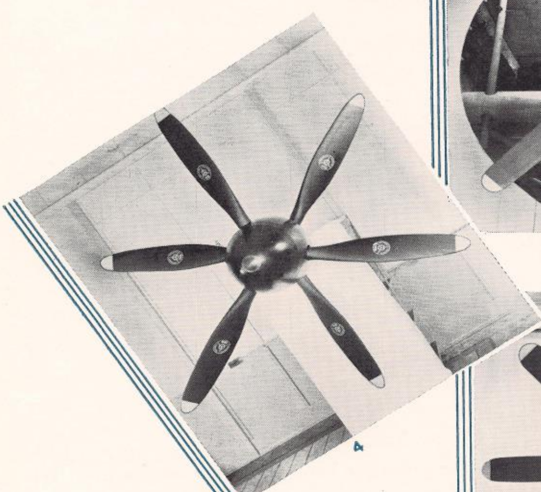

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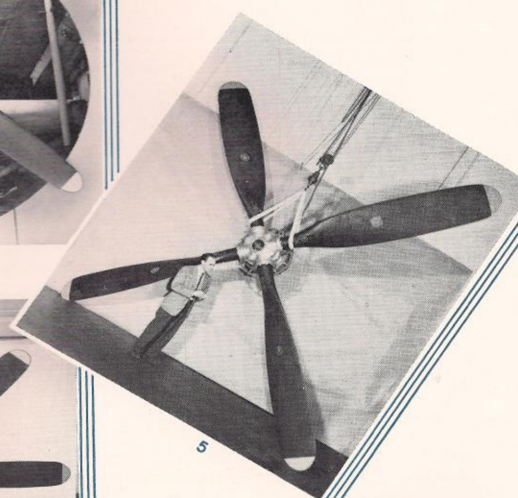

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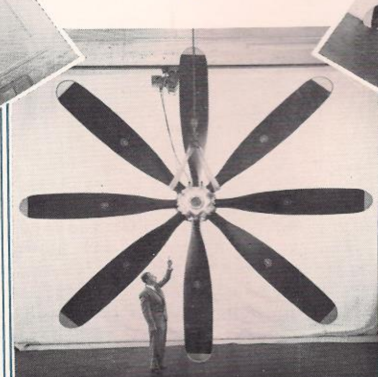


6

No. 1—In 1946, Curtiss propellers were tested on the TG-100 turbo-prop engine installed in the experimental XC-113 airplane. This was one of the first of many such tests made during development of this "Turbolectric" propeller.

No. 2—A B-17, especially modified as a flying test stand for the T-35 turbo-prop engine, built by Wright Aeronautical Corporation, was equipped with five Curtiss Electric Propellers. This photograph shows the airplane in flight, powered by the turbo-prop engine alone, while the propellers on the four reciprocating engines were feathered.

No. 3—A Curtiss Electric Propeller, modified for use on the T-35 turbo-prop was first tested on this special test stand.

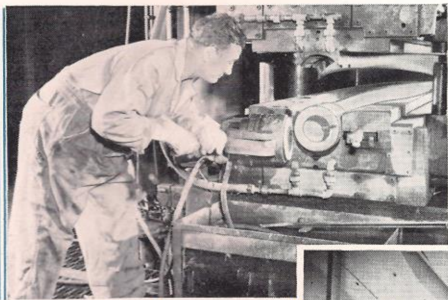
No. 4—This dual-rotation propeller is one of many developed and built by the Curtiss Propeller Division for military application during World War II.

No. 5—This 19' diameter four-bladed propeller is one of the new "Turbolectric" series developed especially for turbo-prop engine application.

No. 6—This huge eight-bladed, 19' diameter, dual-rotation propeller is another in the series of "Turbolectric" propellers developed especially for turbo-prop engine application.

Manufacturing and Testing Facilities

The engineers of the Propeller Division of the Curtiss-Wright Corporation have at their command the finest facilities for building and testing aircraft propellers. Typical examples of these facilities are shown below.



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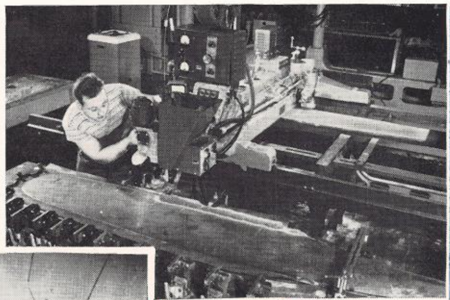

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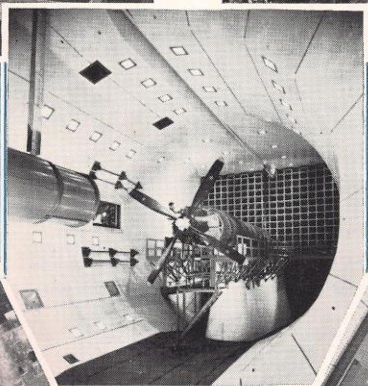

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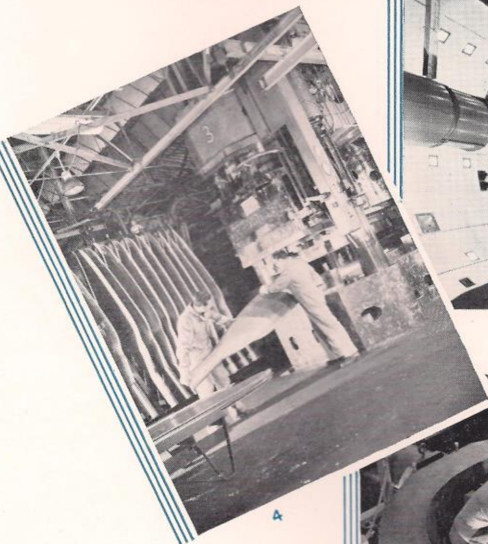

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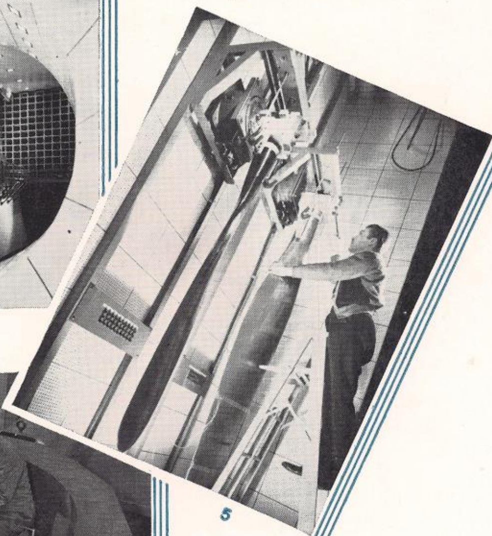

5

6

No. 1—This is one of the highly specialized tools and facilities which expedite the manufacture of Curtiss Monocoque Hollow Steel blades. The red-hot blade is placed in the blade "blow-up die". Nitrogen under high pressure inflates the hollow shell to fit the form of the die, thus imparting the correct airfoil section and pitch distribution.

No. 2—Fabrication time of the hollow steel blade is greatly reduced by the use of semi-automatic welding equipment, which in one continuous operation forms a weld bead around the entire blade.

No. 3—One of the two huge propeller test cells in which propellers up to 30' in diameter may be tested on the actual engines for which they were designed.

No. 4—Huge 2,000-ton presses are used in the stamping and the forming of the shell from which hollow steel blades are manufactured.

No. 5—New blade designs are electro-mechanically vibrated at high stress levels to check their structural characteristics.

No. 6—Propeller hub may be subjected to centrifugal loads equivalent to 600,000 lbs. in this huge hub-testing machine. Gyroscopic and vibratory loads, equivalent to those encountered in flight, may also be imposed if desired.

Let Us Help You!

The Propeller Division of the Curtiss-Wright Corporation will be glad to furnish additional information regarding propellers for your turbo-prop installations. Please address:

CURTISS-WRIGHT CORPORATION
PROPELLER DIVISION
CALDWELL, NEW JERSEY
U.S.A.

THE MODERN PLANT OF THE PROPELLER DIVISION AT CALDWELL, N. J.

Curtiss

ELECTRIC PROPELLERS

FEATHERING

CONSTANT SPEED

SELECTIVE PITCH